Comparison of two approaches for detecting the depth of edge influence on vegetation diversity in the arid valley of southwestern China

LI Li-guang [1,2], HE Xing-yuan [1], LI Xiu-zhen [1], WEN Qing-chun [1,2], ZHAO Yong-hua [1,2]

[1] *Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P. R. China*

[2] *Graduate School of the Chinese Academy of Sciences, Beijing 100039, P. R. China*

Abstract: Three types of landscape boundary (forest/pepper field, forest/cabbage field, and forest/grassland) were selected in the arid valley of upper reaches of Minjiang River, southwestern China. On the basis of vegetation diversity, the depth of edge influence (DEI) on different types of landscape boundaries was estimated using principal components analysis (PCA) method and moving split-window techniques (MSWT). The results showed that in the 5 transects, PCA method was able to detect the edge influence depth with 3 transects, while MSWT could explain 4 transects. It is concluded that PCA and MSWT both can be used to detect the depth of edge influence within 50 m from the edge to the interior. Similar conclusions were drawn in the forest of each transect with the two methods, but no similar conclusions were drawn in the pepper field of each transect. Although the two methods have advantages and disadvantages respectively, they are useful tools for characterizing edge dynamics. Comparing the two methods, MSWT is more successful.

Keywords: Boundary; Moving split-window techniques (MSWT); Principal components analysis (PCA); Depth of edge influence (DEI)

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Introduction

One of the earliest sources of the boundary concept is the work of Clements (Cadenasso *et al.* 2003). At a fine scale, Leopold (1993) concluded that forest edges were an important part of the landscape for wildlife (Chen *et al.* 1996). Now, studies of boundaries rapidly evolve into part of contemporary ecology (Strayer 2003; Fagan *et al.* 2003). In studies of boundary, information on effective edge widths is critical for determining the area of stands available for species dependent on interior habitat conditions, especially for regulatory and management purposes (Matlack 1993; Choesín *et al.* 2002). However, detection of boundaries is straightforward when spatial change in the parameter of ecological and regulatory importance is rapid or sudden. If the magnitude of change is small, even abrupt boundaries may be difficult to be detected (Johnston *et al.* 1992). At the same time, detection of distinct natural boundary line becomes more difficult as change becomes more gradual (Choesin *et al.* 2002). Thus which method should be selected to detect the depth of edge influence (DEI) becomes important.

During the past decades, new equipments and methods have greatly increased our ability to quantitatively study boundaries, which makes it possible to develop and test scientific theories pertaining to boundaries. These methods included multivariate ordination techniques, principal components analysis (PCA), aerial photography and satellite images techniques and moving split-window techniques (MSWT) (Krummel *et al.* 1987; Paster *et al.* 1990; Jin *et al.* 2002; Chang *et al.* 2003). MSWT that was considered a simple but powerful method for analyzing boundary was employed in this paper. At the same time, PCA that was seldom used to boundary determination was employed. The purpose of this study is to detect the depth of edge influence and compare the efficacy of two approaches according to vegetation biodiversity data along on slopes transects in the mountainous area.

Study site

This study was conducted on different boundary types in the arid valley of upper Minjiang River (31°38'–31°51'N, 102°42'–103°51'E), which was on the transitional zone between the Tibetan Plateau and the Sichuan Basin, southwestern China. Climate in the region is characterized by abundant sunshine and low humidity. The average evaporation is above 800 mm per year and aridity is above 1.5 (Tong *et al.* 1996). Rainfall is extremely variable. Average annual precipitation is less than 500 mm, with 80%–90% falling from May to September (Guo *et al.* 1993; Tong *et al.* 1996). The highest air temperature is in July, with an average of 20.8 °C, and the lowest in January at 0.4 °C (Liu 1994). "Foehn effect" is obvious because of complex physiognomy. Elevation of the study area ranges from 1800 m to 3600 m, with steep slopes (>25°). Soil type belongs to dry brown soil and calcareous cinnamon soil. Underlying bedrock is phyllite residual slope deposit (Sun *et al.* 1997).

Sampling design

Five transects were finally chosen from three boundary types including forest/pepper field boundary with upper slope forest and down slope pepper field, on a southwest-facing slope (FP), forest/cabbage field boundary with upper slope forest and down slope cabbage field, on a north-facing slope (FC), and forest/grassland boundary with upper slope grassland and down slope forest, on a south-facing slope (FG). Plant diversity in the cabbage fields (FC) was not investigated because farmers weeded them in order to obtain high cabbage productivity. Therefore the data in the cabbage field were not investigated. Each transect was 5 m wide. For ensuring "capturing" the edge effects on vegetation, length of each transect was 50 m from the

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Biography: Li Liguang (1973-), female, Ph. Candidate in the Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P. R. China. E-mail: llg7308@163.com; llg739039@hotmail.com.

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edge into the forest, pepper field or grassland, respectively. Each transect was divided into 25 small quadrates with size of 2 m × 5 m. In each transect, small quadrates were numbered from small quadrat 1 at the boundary zone to small quadrat 25 in the forest or pepper field or grassland. Abundance, coverage, and height were recorded for each species in each small quadrat and importance value was computed according to recorded data. The field investigation was conducted in late July and October, 2003. The vegetation mainly consisted of coniferous forests, shrubs and herbs (Table 1), (Editorial Board of Sichuan Vegetation 1980).

Table 1. Number of species and main species presented in each transect

Sampling site	Number of species (forest/pepper field or grassland)	Main species	
		Forest	Pepper field or grassland
FP	80/71	*Pinus tabulaeformis, Pinus armandi, Cotoneaster horizontalis, Berberis poiretii Schneid, Artemisia gmelinii, Thalictrum aquilegifolium, Anemone tomentosa*	*Zanthoxylum Piasezkii, Artemisia gmelinii, Astragalus scaberrimus, Stellaria media, Conyz Canadensis, Qxyria sinensio*
FC	70/−	*Sorbaria arborea,,Artemisia gmelinii, Thalictrum aquilegifolium, Anemone tomentosa, Heracleum helmsleyanum, Vicia unijuba, Vicia cracca*	----------
FG	70/51	*Rosa multibracteata, Spiraea schneideriana* var. *schneideriana, Calamagrostis epigeios* (L.) Roth, *Duchesnea indica* (Andrews) Focke, *Artemisa argyi*	*Calamagrostis epigeios* (L.) Roth, *Duchesnea indica* (Andrews) Focke, *Artemisa argyi, Ixeris denticulate*

Analysis methods

Method 1 (principal components analysis (PCA))

Principal components analysis (PCA) was a multivariate statistical technique with wide applications in different disciplines (Wittrock *et al.* 1999). It can be used to select those variables that contain the most information (King *et al.* 1999). In this paper, vegetation data from each transect was analyzed with principal components analysis (SPSS 11.5). PCA was applied to the original dataset, comprising dissimilarity of vegetation at different sampling points. At last, the depth of edge influence can be detected by clustering continuous sample plots.

Method 2 (moving split-window techniques (MSWT))

Firstly, a double window was laid over equal numbers of equally spaced sampling points, and the dissimilarity (distance) between attribute values in each half window was statistically compared. Secondly, the window was moved sequentially along the transect and a series of values that represent successive differences between halves window was produced (Fig.1). At last, the process was repeated until the entire transect was covered. Dissimilarity can be calculated by Square Euclidean distance (Shi *et al.* 2002). It can be described as:

$$SED_n = \sum_{i=1}^{m} (\overline{X}_{iaw} - \overline{X}_{ibw})^2$$

where, n is a station or midpoint between window halves; w denotes the width of the window; a and b represent the two half-windows, respectively; m stands for the variable numbers of each sample plot (Brunt 1990). According to the graph with SED as ordinate and the position of transect as abscissa in Cartesian coordinates, we can determine the DEI of landscape boundary according to the change of the slope.

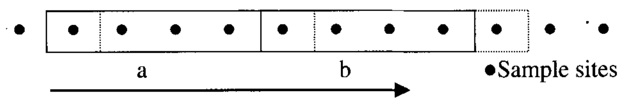

Fig.1 Schematic diagram for the principle of MSWT (a and b represent the semi-windows of moving-split window)

Results

Determination of DEI by PCA

Two groups of continuous sample plots can be identified in the forest of transect FP with PCA (Fig. 2). Sample plots 6–19 (except 11) and sample plots 20–25 (except 21) were clustered clearly. Other sample plots were scattered between the two groups. On the other hand, two groups can be separated obviously in the pepper field part (Fig. 3). One group included sample plots 9–15 (except 12), and the other sample plots 5, 16, 19 and 22–25. Other sample plots were scattered between the two groups, too. In the forest of transect FG (Fig. 4), sample plots 1–9 (except 8) and 10–22 (except 12, 14 and 17) were clustered clearly, respectively.

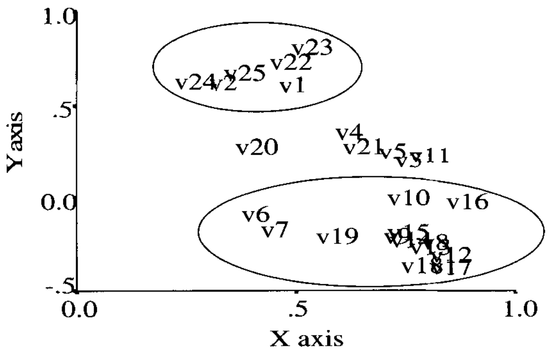

Fig.2 DEI in the forest of transect FP with PCA

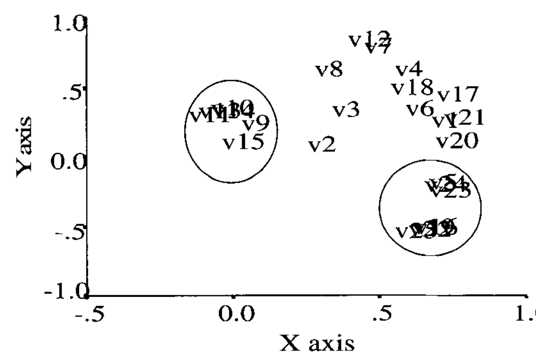

Fig.3 DEI in the pepper field of transect FP with PCA

In the forest of transect FC and grassland of transect FG, no

obvious groups can be identified. Continuous sample plots were not clustered clearly. Some sample plots were also clustered but they were not continuous. Thus the depth of edge influence can not be detected, and the figure was not displayed.

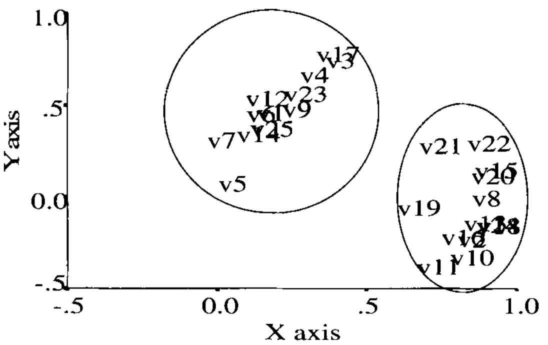

Fig.4 DEI in the forest of transect FG with PCA

Results by clustering to continuous sample plots implied similar characteristics of the vegetation in PCA, but separated sample plots indicated dissimilarity, which suggested the change of vegetation. The distance from the edge to the sample point of vegetation change was considered as the depth of edge influence. According to the above rule, the depth of edge influence was detected (Table 2).

Table 2. Depth of edge influence in different sample sites

Sample site	PCA		MSWT	
	Forest (m)	pepper field or grassland (m)	Forest (m)	pepper field or grassland (m)
FP	22	24	22	30
FC	--	--	--	--
FG	16-18	--	14	22

Determination of DEI by MSWT

When the window width reached 8, the curves of SED became relatively smooth. A peak appeared at 30 m away from the edge in the pepper field of transect FP, and at 14 m in the forest of transect FG, respectively (Fig. 6, 7). On the other hand, when the window width reached 6, two peaks can be identified in the forest part of transect FP, at 22 m and 36 m away from the edge respectively (Fig. 5), and so were in the grassland part of transect FG at 22 m and 34 m distances from the edge when the window width reached 10 (Fig. 8). Stable peak in the curves of SED did not occur when the window width changed from 2 to 14 in the forest part of transect FC. Therefore the depth of edge influence was not detected.

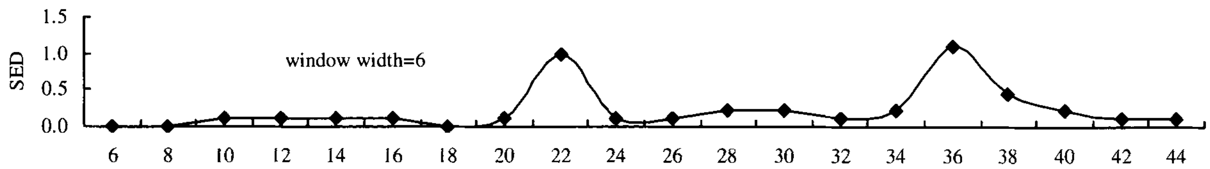

Fig.5 DEI in the forest of transect FP with

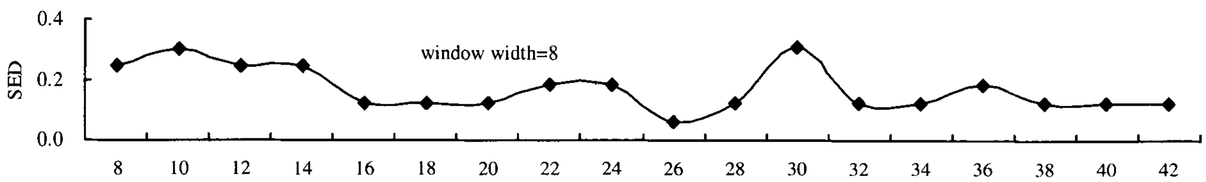

Fig.6 DEI in the pepper field of transect FP with MSWT

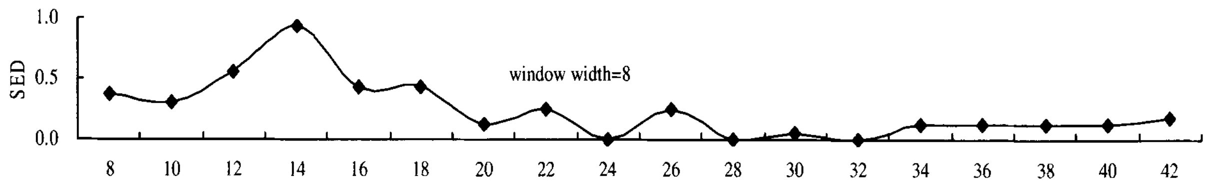

Fig.7 DEI in the forest of transect FG with MSWT

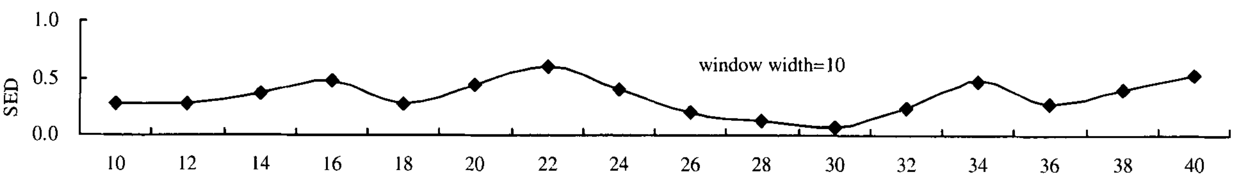

Fig.8 DEI in the grassland of transect FG with MSWT

Smaller window widths produced high sample-to-sample noise, whereas important information was lost when using a larger window width. However, when the window width reached an appropriate width, obvious and stable peaks would appear in the curve. The distance from the edge to the peak was considered as the depth of edge influence. According to the above rules, the depth of edge influence in different transects can be delineated (Table 2). In this study, the distance from the edge to the sample plot that vegetation changed for the first time was considered as the depth of edge influence.

In particular, two peaks occurred in the forest of transect FP and in the grassland of transect FG. The second peak appeared because of the "boundary" between sparse forest and dense forests at 40 m into the forest part of transect FP. This "boundary" influenced the temperature, humidity and illumination. Therefore the similarity of vegetation was changed. The second peak in the grassland part of transect FG appeared because of the sudden change of slope gradient at 38 m from the edge to interior of grassland part of transect FG.

Discussion

PCA and MSWT both can be used to detect the depth of edge influence. However, the depth of edge influence was different for different types of boundaries. The depth of edge influence can be estimated within 50 m from the edge to the core area on both sides. Similar conclusion was drawn by Murcia (1995). Comparing the results from the two methods, similar conclusions were drawn in the forest of each transect, but there was no similar conclusions in the pepper field of each transect.

As PCA and MSWT were used in this study to analyze the same data, a direct comparison can be made between their effectiveness. First, in the 5 transects, PCA analysis was able to resolve 3 transects, while MSWT analysis can explain 4 transects. Secondly, similar conclusion was drawn from the two methods in the forest part of transect FP where the slope gradient was under 15°. Thus, the two methods were concordant in DEI determination when the slope gradient of transect was relatively gentle.

Even in cases where it appears that PCA has resolved the various vegetation zones, it is difficult to separate the sample plots into groups solely by subjective examination of the ordination space. Furthermore, DEI can not be detected when the discontinuous sample plots clustered. On the other hand, MSWT explains clearly and directly the DEI of most transects according to the peaks in the curve. But the peaks will not be obvious if similarity between sample plots is not close.

Although the two methods have advantages and disadvantages respectively, they are useful tools for characterizing edge dynamics. Comparing the two methods, MSWT analysis was more successful. Of course, the appropriate methods should be selected, based on the particular objectives and the questions. So far no standard theories or techniques have been formed for the detection of DEI because of their complexity. Therefore new methods are still indispensable for detecting the DEI in future study.

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